# ELEMENTS AFFECTING CONSTRUCTION

# OF POWER PLANTS

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This subject covers a good deal of ground and the discussion will be limited to the planning and methods used in selecting sites for power plants. We are concerned with three types of plants, Hydro, Internal Combustion and Steam.

## HYDRO ELECTRIC PLANT

We shall consider a hydro plant first. Before a loan for a hydro plant is made a "Hydro-Electric Potentialities Survey" must be submitted. The board of directors selects a qualified project engineer who may or may not be the preloan engineer. The "Hydro-Electric Potentialities Survey" does not go into design detail and if in our judgment additional factual information is required before a loan can be made a more detailed report is requested.

All previous investigations that have been made are reviewed and present investigation of the site is made, giving reasons and recommendations for plan of development selected. Some of the main headings that are included in such reports are:

a. Topography

b. Hydrology

c. Geology

d. Federal and Territorial Jurisdiction

### Topography

A topographic map of the site under consideration which will show natural features, man-made features, and location of materials which can be incorporated in the dam. The topographic map should have five-foot contours.

### Hydrology

A study is made of the stream flow of the stream involved. The engineer investigates all pertinent data including climate, rainfall, snowfall, temperature variations, ice conditions, wind direction, and amount of evaporation. A study of the stream flow at the site under consideration is made showing variation during seasons of the year. He also prepares hydrographs of the average, minimum and maximum years as well as duration curves. Power duration curves are prepared to show the initial and ultimate installations of generating equipment.

### Geology

The engineer is expected to study the general geology of the areas. This is done by core drilling, test pits and any other methods that will show the strata of the ground in the area considered for construction of the dam. Soils in the area have to be analyzed for possible use as dam building material. The engineer is expected to prepare a proposed plan of construction showing details such as material, size, shape, length, height, and capacity, etc. He is expected to give reasons for using the particular design considered.

### Federal and Territorial Jurisdiction

The engineer shall look into the need for permits, licenses, franchises or any other authorization that the Owner might be required to obtain from the agencies having control. Some of the agencies are Federal Power Commission, United States Geological Survey, Forest Service, Fish and Wildlife Service, Bureau of Reclamation,

National Park Service, and the Territorial Government of Alaska. There may be some local Government requirements that may also have to be satisfied. It is the responsibility of the engineer and project attorney to look into the matter of permits and instruct the Owner how to proceed in obtaining them.

After the engineer studies the above items, he supplements his thinking with drawings and data on the following:

a. A mass-flow diagram or reservoir operation diagram showing the effect of power production if carry-over storage is provided. The effect of pondage on power peaking shall also be illustrated or described.

b. Curves showing the effect on stream flow by use of storage or pondage for power purposes, including peaking, particularly where prior water rights might be affected.

c. An area-capacity curve of the reservoir indicating usable and dead storage.

d. A profile of the river for the reach between the upper limits of the reservoir to a point one-half mile downstream of the damsite.

e. Economic Details:

(1) A feasibility study based upon the adequacy of the stream and the plant to develop sufficient power to supply the electric requirements of the system as indicated by existing and estimated future load data supplied to the Engineer by the Owner.

(2) Recommendations as to the type and size of dam or diversion dam; penstock, flow line and/or canal; and generating units which may be necessary to provide for the load requirements of the power system for the initial and ultimate installation.

(3) Recommendations as to the most practicable method of operation to adapt the plant production to the power system requirements.

(4) An estimate of the quantity of material and the unit cost thereof for developing each Structure, and an estimate of the cost of the equipment to be installed, all in accordance with the Federal Power Commission Uniform System of Accounts, including the cost of land, water rights, licenses, franchises and any other relevant items of expense.

(5) An estimate of the average annual charges, including operation and maintenance, taxes, insurance, public liability, FPC charges, interest and amortization of the loan and any other items of annual expense that may be incurred.

The engineer then submits five copies of this report to the Owner and Administrator for approval. The Owner or the Administrator may ask the Engineer to amplify or supplement the report if necessary.

## STEAM ELECTRIC PLANTS

The site selection report for a steam plant is one of the requirements of the Engineering Service Contract (REA Form 211). The precondition of a steam-electric generating plant is that water and fuel be available. Other factors, too, must be carefully weighed in the selection of a site for such a plant. In general, the considerations are as follows:

a. Water supply

b. Topography

c. Subsoil conditions

d. Fuel (supply and storage)

e. Relation of plant site to electrical load center

f. Transportation facilities

g. Adequacy of site for expansion

h. Disposal of waste products (fly ash, ash)

j. Amenities for employees

k. Taxes

No one site being ideally situated in respect of all the considerations cited above, several suitable sites should be selected and options to purchase should be secured on all of them. This will in most cases prevent exorbitant price rises for the real estate involved. A good source of information concerning available sites are the offices of the transportation companies serving the vicinity of the proposed plant. Care, however, must be exercised in the evaluation of information so obtained where competing railroads or barge lines serving different coal fields supply the data.

### Water Supply

Water is used in the steam-electric generating plant for two purposes: (1) for cooling and (2) for replacing the loss of water in the steam cycle or in the cooling system if cooling towers are used. Sources of water are generally rivers, lakes and in exceptional cases, wells or the sea.

1. For condenser cooling purposes, ample quantities of cold water are necessary in the immediate vicinity of the plant. If the cooling water is not recirculated to a cooling tower, a site adjacent to the sea, a fairly large lake or a flowing river becomes mandatory. In exceptional cases, the river may occasionally run dry on the surface of the ground, forcing reliance upon large capacity wells to tap the underground cool water supply.

2. When the plant site is beside the sea, a lake or river, variations in the level of the water source must be determined, including maximum tides, high water, flood and drouth levels.

3. With a water supply from a source of sufficient depth, such as deep rivers and lakes, the site should permit the intake to be located below the thermocline (plane below which the water temperature remains constant regardless of atmospheric temperature changes). This plane is normally at a depth of about 15 feet below water level, in the case of fresh water lakes. The water below the thermocline is often 5 to 15° F cooler than surface water.

4. Where sewage or industrial wastes are emptied into rivers upstream or into lakes in the vicinity of the proposed plant, the water must be checked for the presence of acids injurious to plant equipment, molasses, algae or bacteria promoting growth of algae whose presence may lead to serious problems of corrosion or clogging when the condensers are in service.

5. The site should be such that water can be discharged without the danger of recirculation except in northern climates where provisions must be made for recirculation during freezing weather to keep the intake open.

6. The water from rivers or lakes is usually taken into the plant through a conduit with the pumps located either at the water's edge or at the plant itself and discharged through another conduit. The pumping head imposed on the circulating water pumps must always be considered and perhaps evaluated. If it is unusually large, the possibility of reclaiming a portion of it by syphons or other means should be determined as well as the cost of doing so.

7. Where the natural flow of water is limited, cooling towers or spray ponds are used.

8. The boiler feed-make-up water is usually taken from the cooling (circulating) water supply. It is then filtered, chemically treated, evaporated and introduced into the steam cycle. In exceptional cases it may be taken from wells. In arid regions or regions of bad surface water conditions, a thorough investigation will be required. Since cooling towers are frequently used in such regions, the water investigations should be carried out under the direction of a specialist versed in this type of work.

<u>Topography</u>

In determining plant sites, the use of topographical maps of the Unites States Geological Survey ("Topographical Sheets") aerial photographs, and Corps of Engineers' river maps are of high value.

Level ground of sufficient area for the ultimate plant development, including ancillary structures and a parking area for employees should be available in order that earth moving costs will be at a minimum. Plants have been located on hillsides, but great care must be exercised to take the best possible advantage of the terrain so as to minimize earth-moving. In such locations the layout of transmission lines must be determined so that especially expensive construction may be evaluated.

A factor sometimes overlooked where hills adjoin the plant are prevailing winds. They may influence chimney draft considerably and create a nuisance problem due to down-wash from the plant stacks. This becomes especially important in the vicinity

of settlements as the neighbors already prone to object to plant noises, may complain that their properties are further damaged by the intolerable conditions arising from coal dust from the storage area and fly ash and flue gases from the stack. Prevailing winds should also be taken into account when locating the plant step-up substation. The latter must be so located in relation to the coal stocking area that the blowing of coal dust onto the substation is minimized.

Prevailing winds also have a marked effect on plants equipped with cooling towers as spray from the towers may be carried quite a distance. It is important, therefore, to locate the towers in such a manner that no spray can be carried by the prevailing wind to any part of the plant where outdoor equipment, especially the substation, could be adversely affected, or to any neighboring property.

All these considerations must be studied most carefully where seaside sites seem to be advantageous, because of the serious effect of the fogs forming in such locations upon all electrical equipment as well as upon steel structures.

Except in seaside areas the plant should be located if at all possible directly on the water's edge. The presence of highways, railroads or other structures skirting the water front must be given serious consideration. The crossing of these obstacles by circulating water tunnels, spur tracks and overhead wires requires permits or easements and results in considerably increased cost of the plant in many instances. The plant site including the essential means of access by road (and by rail if solid fuel is used) should be at least five feet above highest recorded flood level. If due to unavoidable circumstances, the surface or ground water level can ever rise above the lowest floor level in the plant, the plant in itself must be calculated for buoyancy and provisions must be made to bulkhead all openings to five feet above the highest recorded flood stage. Furthermore, regardless of plant location the plant design will require checking with the Civil Aeronautics Administration as to the permissible height of the stack, required airplane warning lights, etc.

## Subsoil Conditions

The State Geologist and the United States Geological Survey must be consulted to ascertain the probable subsurface conditions which will exist in the vicinity of each site considered. Subsurface structures may easily be the most expensive part of a plant, and the possibility of later subsidence of the site when loaded by the plant must always be investigated by geologists.

When it has been determined that future hazards can arise on the site a thorough study of the subsurface strata should be undertaken at all sites under option or at the sites which other considerations indicate to be the most desirable. In most cases, a reliable estimate of per unit cost cannot be made without deep test borings and the results of these drillings should be authoritatively interpreted by a recognized laboratory. Sites requiring long piles to reach a firm subbase should, if possible, be avoided. Sites on alluvial sand and silt require spread foundations which are expensive and tend to differential settlement. Quicksand especially poses problems of this nature and like gumbo soils, should be critically examined. When gravel beds under the site are encountered their depth should be carefully determined to see whether or not they provide adequate support for heavy loads. In glacial gravel deposits, nests of boulders may be present rendering construction difficult and expensive. Clay and sandy soils may require friction piling. In general, no site should be considered where there is any possibility of settlement when later additions to the plant are made. In an economic comparison of sites the considerations mentioned must be thoroughly discussed.

Fuel (Supply and Storage)

As REA-financed plants are amortized on a 35-year basis it is vitally important that an adequate fuel supply for the ultimate development of the plant be assured over the life of the loan. While not absolutely necessary, it is to the best interest of the Owner that more than one type of fuel be available. This usually results in keeping alive competition between different fuels and thus will allow the borrower to use the fuel which at the time of purchase is the most economical. If the advantages of some particular site are outstanding in all other respects, but only one source of fuel is available at that site, the long-term assurance of the availability of that fuel and its cost must be most critically examined.

Solid and liquid fuels are normally received by railroad, truck or barge, and gaseous fuels by pipe line. Adequate unloading facilities for solid and liquid fuels such as car shakers and dumps, hoppers, clam shell drag-lines, oil pumps and in northern climates, car thawing sheds and oil heaters, must be provided, with the necessary special switching and trackage. Where cheap water transportation is available for solid fuels the storage area and trackage for emergency rail shipments in winter, will be important and lastly, where liquid fuels are available by water and by rail oil tanks, pipe lines, car and barge unloading equipment and pumping facilities for both methods of transportation must be determined as to area necessary and cost as well as the trackage and switching required for rail shipment. Special attention should be directed to assure that unloading facilities are above flood level. Storage for solid fuels requires an area of sufficient size to store enough supplies for at least three months' operation of the plant. Where fuel is brought in by water, an eight months' supply in northern climates, becomes minimum. Determination of the permissible height of the storage pile must be made as this will vary with type of fuel, due to the varying risk of spontaneous combustion. Provision should be made in plant layouts and in estimates of plant capital costs and operating expense so that water borne and rail borne coal can be unloaded, delivered either to storage or to the bunkers, and compacted economically. Even in plants which are intended to use liquid or gaseous fuels it is necessary to consider that, in the future, it may become necessary or economical to burn coal. This may happen either by gas or oil fields becoming exhausted or by economic dislocations making fuels other than coal prohibitively expensive. Thus, if there is even a remote chance of coal ever being used it is imperative that a site be selected which affords a sufficiently large area for storage of coal and disposal of ash.

Storage for liquid fuels is provided by tanks. Storage for a six weeks' supply is considered satisfactory in most cases, but special conditions may require a larger storage. Particular attention must be given to provisions such as dikes, for safeguarding the property from eventual rupture of a tank. Where oil is used as a standby or for lighting off pulverized fuel boilers, a few days' supply for each unit may prove satisfactory.

Plant Site and Load Center

Transmission lines with their associated substations are costly. The ideal plant site, therefore, is one requiring the least amount of transmission from the plant to the user, i. e., a site at the load center. The importance of this factor varies with the load density, being greatest in urban centers and diminishing with the small load density of rural systems.

As it is rarely feasible to locate a steam plant having the best water supply, topography, subsoil conditions and fuel supply, exactly at, or close to, the load center of the system to be supplied with energy, an economic comparison of the total project capital cost and operating expenses for each of the various sites including the necessary transmission facilities must be made, with special consideration given to the high cost of river crossings. In estimating operating expense, consideration

must, of course, be given to the economic evaluation of transmission losses and regulation of transmission lines as between the various sites. In locations at the foot of a hill, serious attention must be paid to methods of routing transmission circuits out of the plant substation and to the adequacy of the area selected for the substation.

Transportation Facilities

The plant receives not only fuel via rail, barge or truck, but also, during periods of construction, heavy equipment.

In case water transportation is contemplated, docking facilities will have to be provided. This may require negotiations with, and construction permits from the Corps of Engineers. It is advisable to make a preliminary check with that agency to explore its standing on docking facilities. Furthermore, barge unloading facilities must be provided. As our northern waters are ice bound during part of the year, alternative transportation facilities must be provided where shipping is suspended at certain times.

Railroads in the vicinity of the plant sites should be approached to ascertain freight rates to the different sites selected as the rates may vary considerably between them. Adequate switching tracks must be provided to receive and store the maximum number of cars which may be delivered at any one time, when the plant is expanded to its ultimate size. A transformer transfer track at the substation is a convenience in handling heavy power transformers; thus consideration should be given to a site layout which facilitates such an approach to the railroad track that the transfer of a transformer from a flat car to the transfer truck will be easy. Spur tracks for plant services should be laid out in such a manner that they do not preclude future expansion of the substation, that they are not in the way of outgoing high tension lines and that they do not require a multiplicity of grade crossings outside of the immediate plant area. Where trucking is necessary and heavy equipment must be handled into the plant in this manner, care should be exercised to make sure that highway bridges are sufficiently strong to take the heaviest load expected. State highway departments are a good source of such information.

Adequacy of Site for Expansion

Power plants grow with the systems they serve. With shifting load centers, however, additional capacity after the initial installation, may have to be located remote from the original plant. Even though it may be foreseen that this will occur, sufficient real estate for expansion must be provided at the initial site because of unforeseen developments which may dictate expansion of the original plant as a later step.

Of course, care should be exercised that in the planning of ultimate station capacity and, therefore, of size of plant site, the limits of the water supply be not exceeded by the demand for circulating water. If the natural water supply is limited, the maximum plant capacity which can be served by it must be stated in the site report and the other sites which may require development to meet the maximum ultimate system loads must receive such attention as will enable the owner to visualize clearly the problems he will meet during the life of his property.

Special attention should be given to expansion of substation facilities, particularly at the higher voltages from 69 kv up and to the feasibility of additional lines issuing from the substation. The latter consideration may require ingenuity in the use of dead end and other special structures.

Waste Disposal

In contrast to other industrial installations a power plant has few fluid wastes, but a large quantity of gaseous and, if coal burning, solid wastes.

The disposal of the solid products of combustion, ash and fly ash, is a serious problem where low areas for fill are inadequate for long-term storage. This problem is of the order of the lifetime of the plant. A South American plant laid out to burn coal rich in ash had to be converted to oil fuel after about 15 years because all areas low enough to store ash had become filled up. It is often possible to sell the ash from stoker-fired boilers whereas slag and fly ash from pulverized coal-fired plants must be disposed of at some cost to the owner. Where the latter wastes have to be hauled away to distant fill areas the cost for such transportation has to be figured in the cost of operation and may become a factor in the selection of a site.

State and federal authorities must be consulted in regard to contamination of streams, lakes, surface waters and the sea by waste products from the plant.

The gaseous wastes such as sulphur in the flue gases and carbon dioxide (as well as fly ash) may require special treatment equipment (dust catchers, scrubbers, $CO_2$ inverters) to reduce their nuisance effects upon nearby settlements. This raises the plant investment and may favor a plant location more remote from neighbors than one close to a village or town. The effects of such stack discharges upon agricultural and horticultural operations and upon trees must also be considered.

Amenities for Employees

A consideration often neglected is the recruiting of employees for operation and maintenance of the station. Adequate housing for operators should be available at reasonable prices; good schools, stores, churches should be near the plant and good roads giving easy access to the plant at all times. As most employees have automobiles adequate parking areas must be provided. The results of not giving sufficient attention to this subject may render it impossible to hire competent personnel at the prevailing wage rates.

Taxes

A further factor influencing the selection of a proper plant site is the tax rate in those states which levy property taxes on cooperatives. Two elements enter into the calculation of the annual tax burden: the percentage of the plant value at which the property is assessed and the rate per hundred dollars of assessed value which is levied against the property. As these factors may vary greatly from county to county and from state to state, they must be taken into account in the calculation of the fixed charges against the plant. The engineer and the Owner's attorney should collaborate in advising the Owner regarding current and future taxation for each site considered.

Since State laws on taxation are subject to amendment or repeal the assumption that full tax rates may be levied in later years should always be made in calculating long-term average tax levels.

Site Report

A site report should discuss in detail all the foregoing points for each site under consideration carefully weighing each point and balancing one against the other. Tabulations showing quantitatively as well as qualitatively the various components going into the evaluation of the different sites must be a part of the report. Pertinent topography should be included, as well as copies of correspondence from railroads and other transportation agencies, fuel suppliers, State Geologists, United States Geological Survey, Civil Aeronautics Administration, United States Corps of Engineers, also aerial and terrestrial photographs of the sites, etc. The final part of the report should sum up the reasons why a certain site is considered superior to all others.

The report should always be prepared having in mind that those reviewing it must be so fully informed that they can reach independent conclusions regarding each factor considered and the final recommendation.

Internal Combustion Power Plants

Site selection for an Internal Combustion plant is similar to that of a steam plant. Those that apply are listed below:

a. Water supply

b. Topography

c. Fuel

d. Relation of site to electrical load center

e. Adequacy of site for expansion

f. Amenities for employees

g. Taxes

In general the same elements apply to both types of plants.

Most Internal Combustion plants are cooled with cooling towers or radiators and the water supply is most generally shallow or deep wells. The engineer should investigate existing wells in the vicinity by checking with the State Geologist who usually has logs of wells drilled. It may be necessary on some occasions to drill a test well to determine the location of water bearing strata.

The plant should be located on a site that has good drainage and also good soil for foundations. The engineer should examine fuel supply carefully as Internal Combustion engines can burn both or either gas or oil. The location of gas lines, existing or proposed, should be considered in selecting the plant site. Transportation facilities, both highway and railroad should also have some bearing on location of plant as trucking fuel oil versus rail transportation may have a great deal of effect on the operation of the plant in the future.

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